Electricity Markets Complex Adaptive Systems (EMCAS) Model

A New Long-Term Power Market Forecasting Tool

Guenter Conzelmann
Center for Energy, Environmental, and Economic Systems Analysis (CEEESA)
Argonne National Laboratory (ANL)
9700 South Cass Avenue
Argonne, Illinois 60439, USA

phone: 630-252-7173 fax: 630-252-6073
email: guenter@anl.gov

Argonne National Laboratory is a
U.S. Department of Energy research center
operated by the University of Chicago.

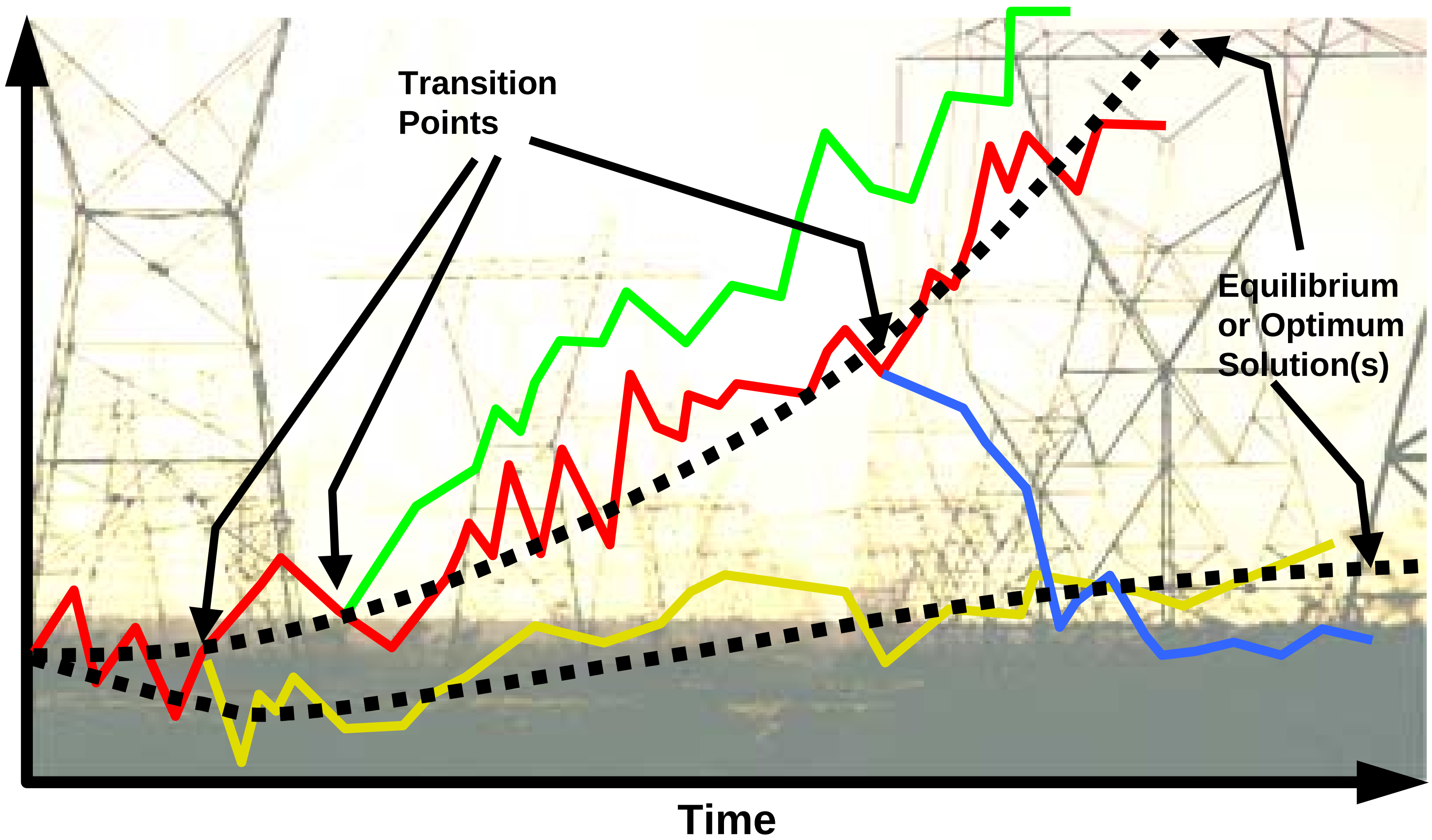
To Address Market Participant Behavior, EMCAS Uses an Agent-Based Simulation

- **Represents multiple market participants (agents) with decentralized decision-making**
- **Incorporates agent learning and adaptation based on performance and changing conditions**
- **A wide range of market strategies are available to the different agents**
- **User-specified market rules affect the behavior of individual agents as well as the system**

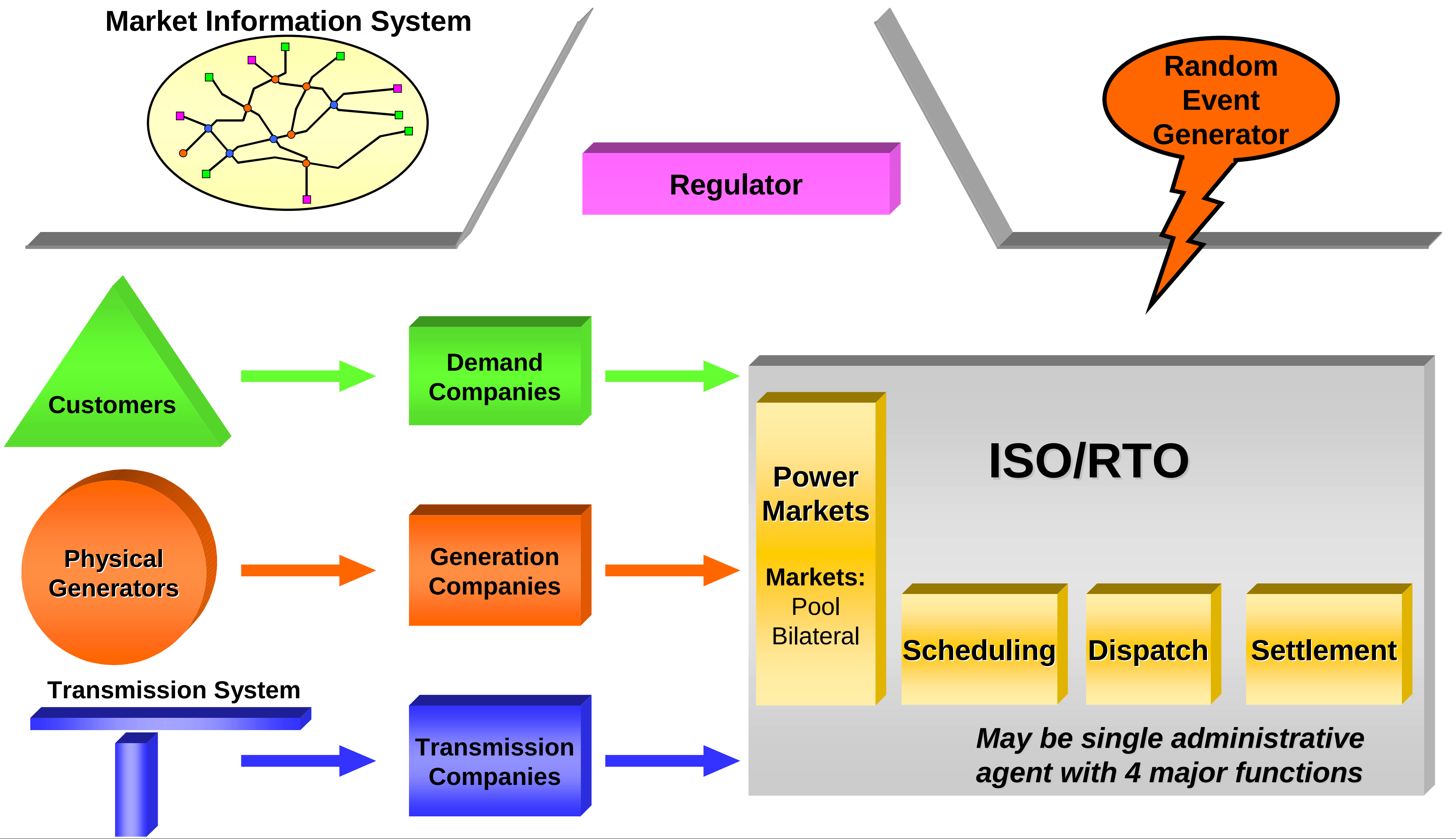
"[Agent based simulation] has considerable similarity to the mathematical theory of games of strategy, but, unlike the generalized games solved by von Neuman or Nash, these are repeated games with non-zero sum payoffs."

A.M. Wildberger, EPRI

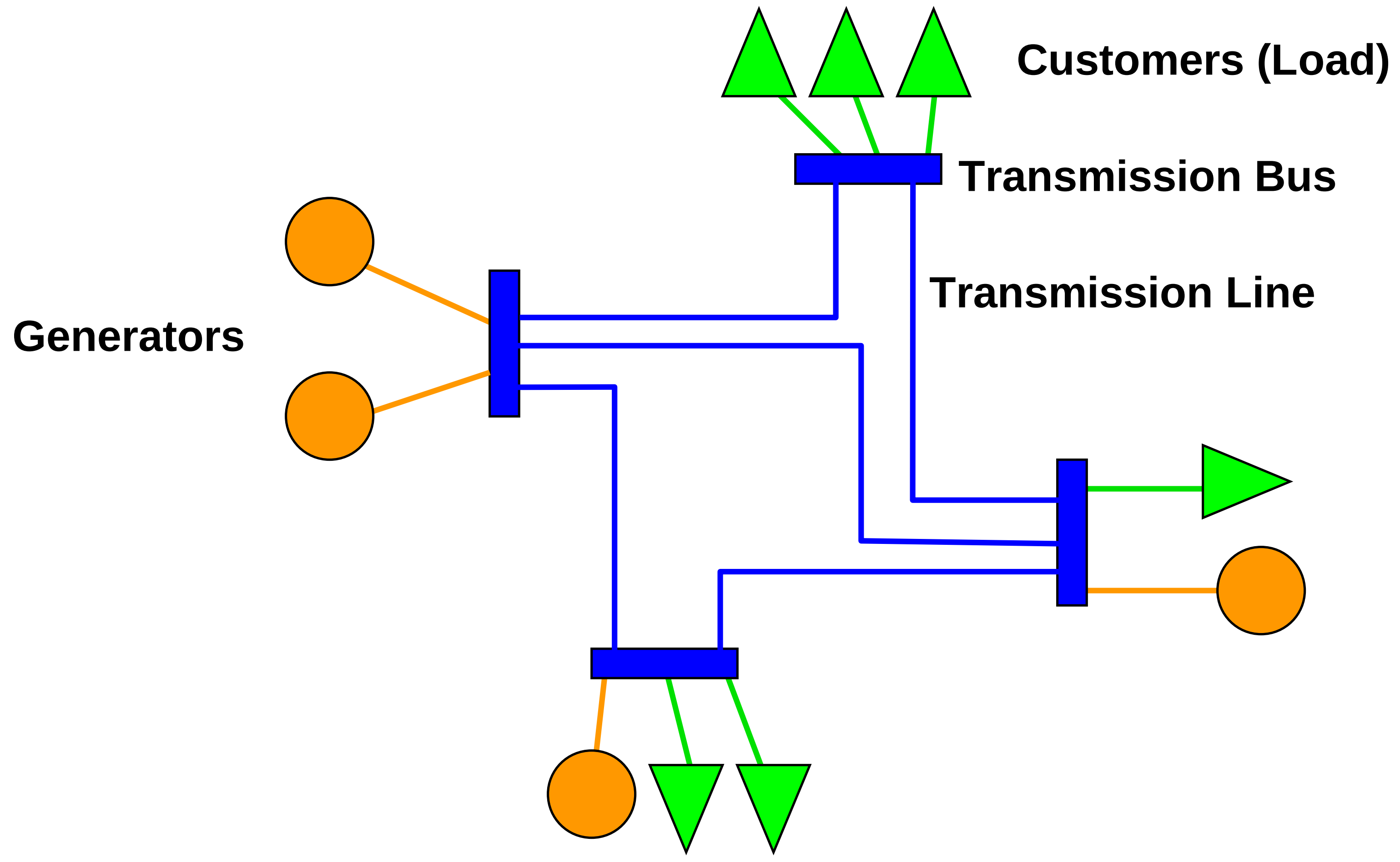
EMCAS Is Designed to Determine the State(s) that the Market Will Gravitate Toward, and the Transients Involved in Getting There



EMCAS Uses an Agent-Based Architecture to Represent Participants in the Electricity Marketplace



Generators, Transmission Nodes and Links, and Customers Form the Physical System Configuration



Generators and Transmission Nodes/Links Are Characterized by Technical and Cost Parameters

Generator

Capacity
Heat rate
Ramp rates
Fuel cost
O/M cost

Transmission
Bus
Line

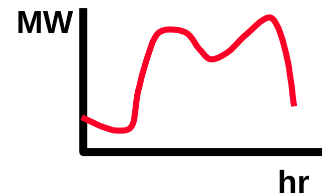
Capacity
Voltage
Line loss
O/M cost

These are physical components and have no decision capability

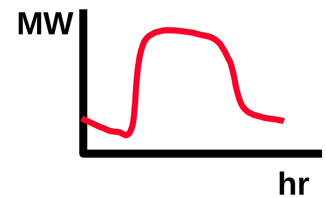
Customer Agents Represent Electricity Users

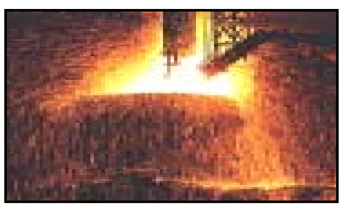
Load profiles

Residential

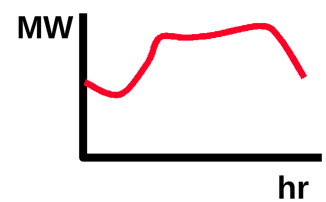


Commercial





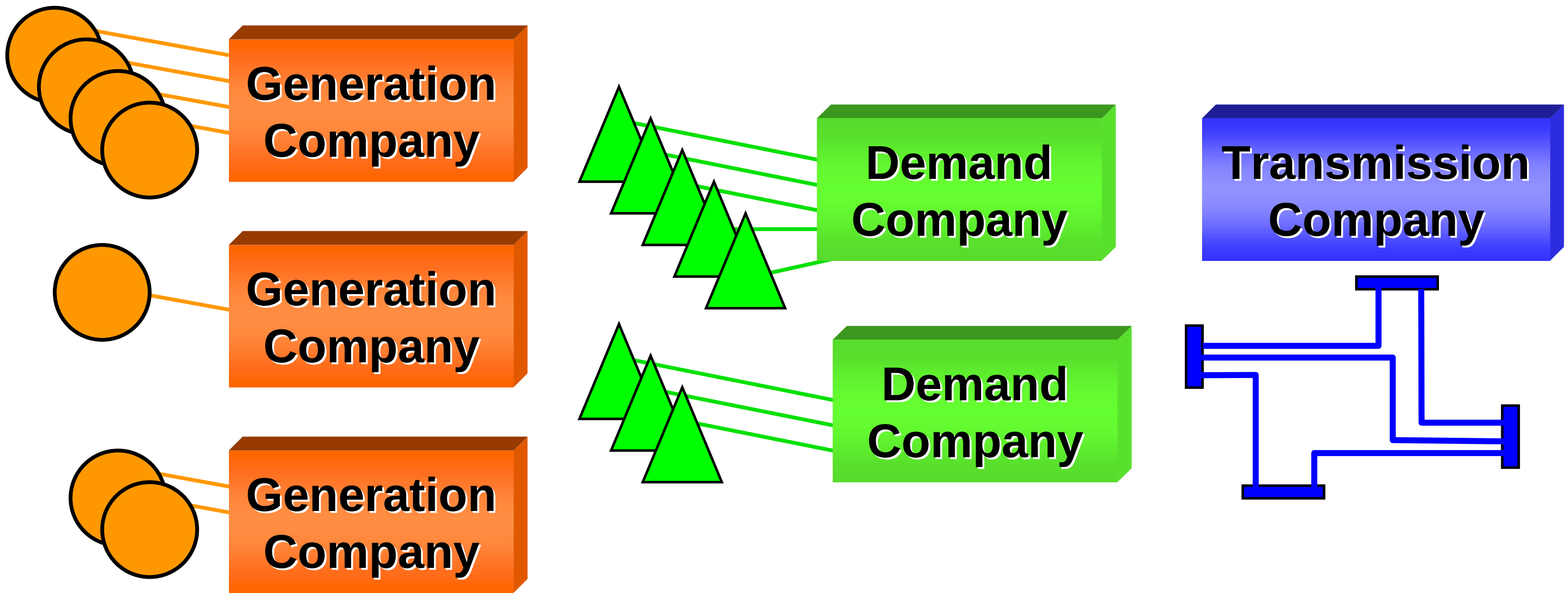
Industrial



Customer agents have choices at different times

-Quantity of electricity purchased
-Supplier
-Contract terms

The Company Agents Represent Business Operations



Revenue:	Sales of generator output	Charges to customers	Transmission charges
Costs:	Fuel, O/M costs, capital	Purchases of electricity	O/M costs, capital

In EMCAS, Company Agents Seek to Maximize the Corporate Utility Function, Not Overall Social Utility

- **Each company agent can have a set of corporate objectives**
  - Profit
  - Market share
  - …other…

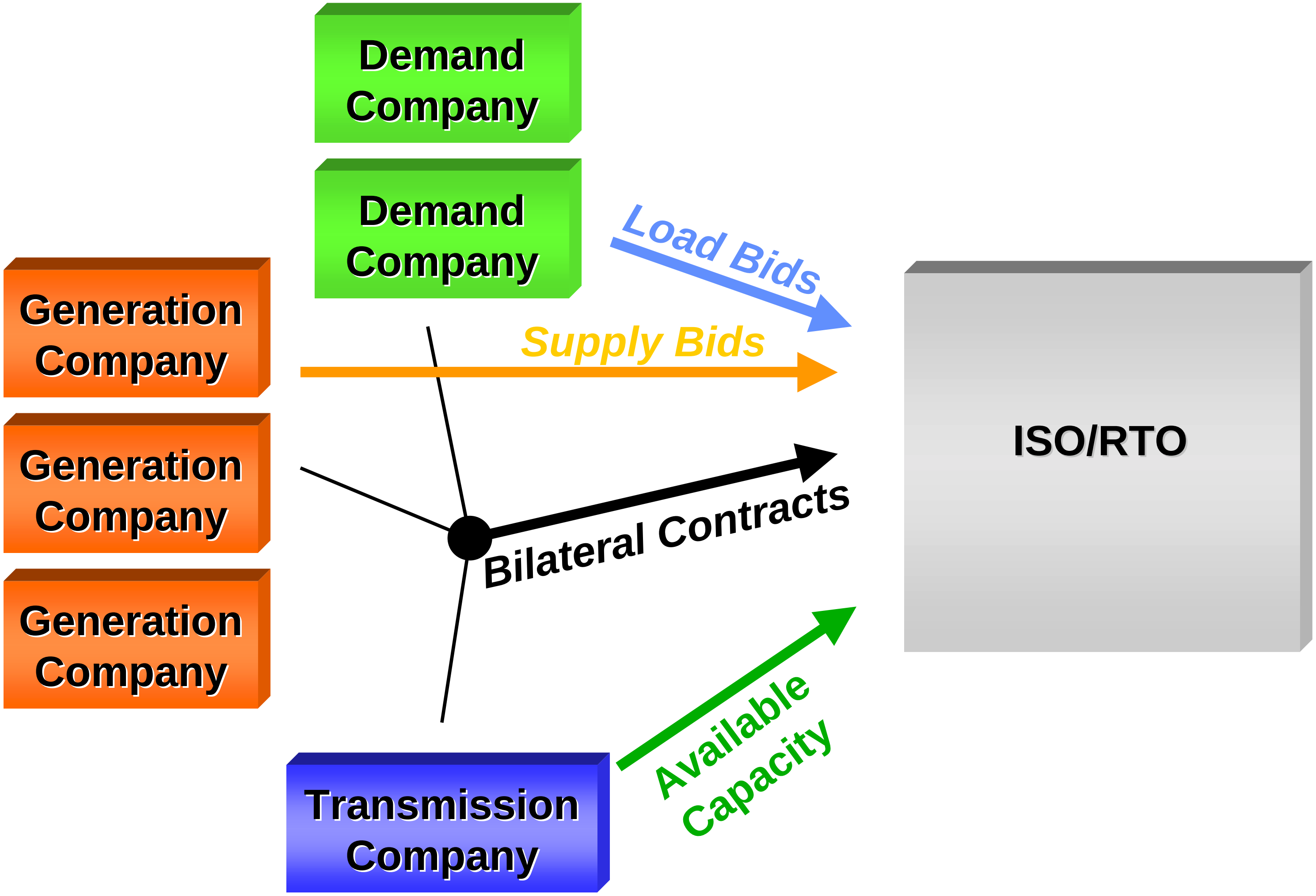
- **Multiple objectives can be combined into a utility function**

Utility Function = f (Profit, Market Share, ..other..)

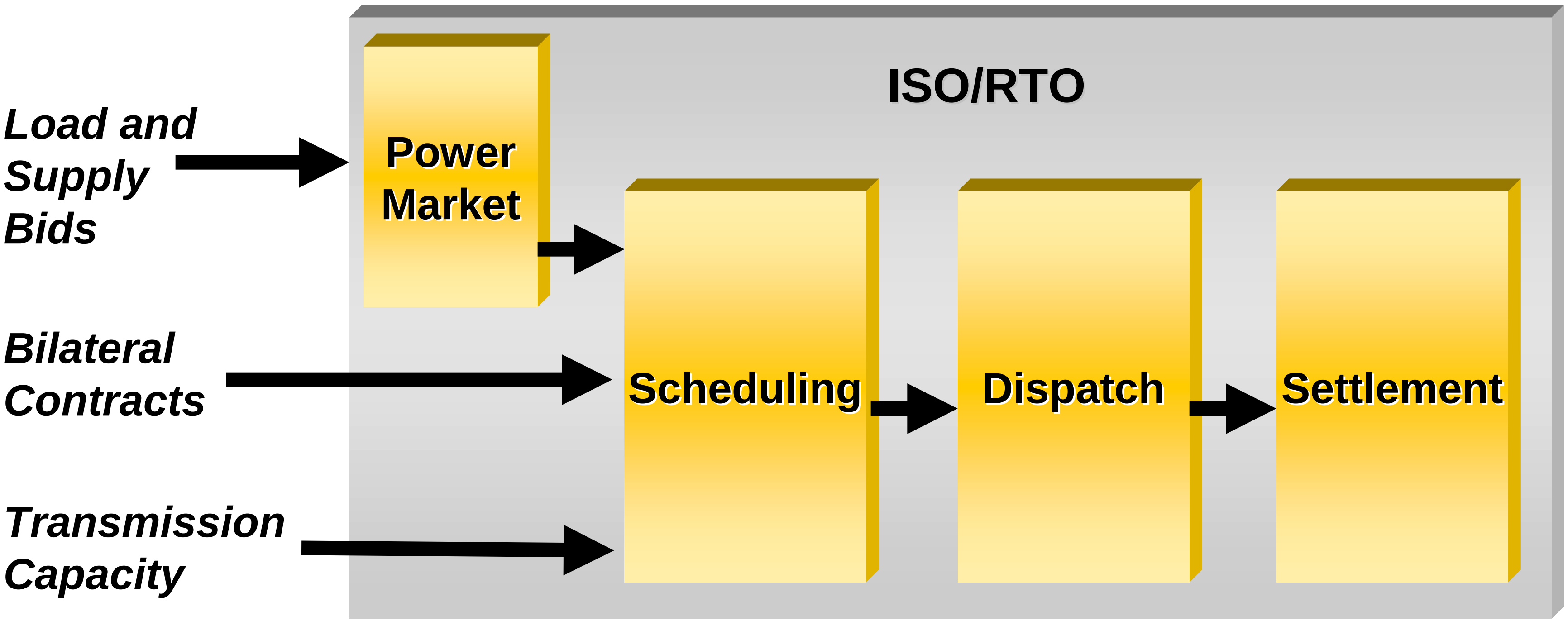
Not all companies necessarily have the same objectives

Not all companies necessarily use the same utility function

In the EMCAS Environment, the Company Agents Interact with Each Other and with the ISO/RTO



The ISO/RTO Has Four Major Functions



User Inputs Control Key Parts of the EMCAS Simulation

Regulator

Sets market rules

- -Bidding rules
- -Bilateral contract rules
- -Settlement (reimbursement) rules

Special Event Generator

Creates special situations

- -Generator outages
- -Transmission outages
- -Unexpected load changes
- -Fuel price changes

The Market Information System Is the Source of the Information that Is Available to All Agents: The Bulletin Board

Market Information System

System load projections

Scheduled outages

Available transmission capacity

Historical market clearing prices

etc.....

At Each Level, the Agents Exchange Information and Decide Among Options Available to Them

EXAMPLE: GENERATION COMPANY AGENT

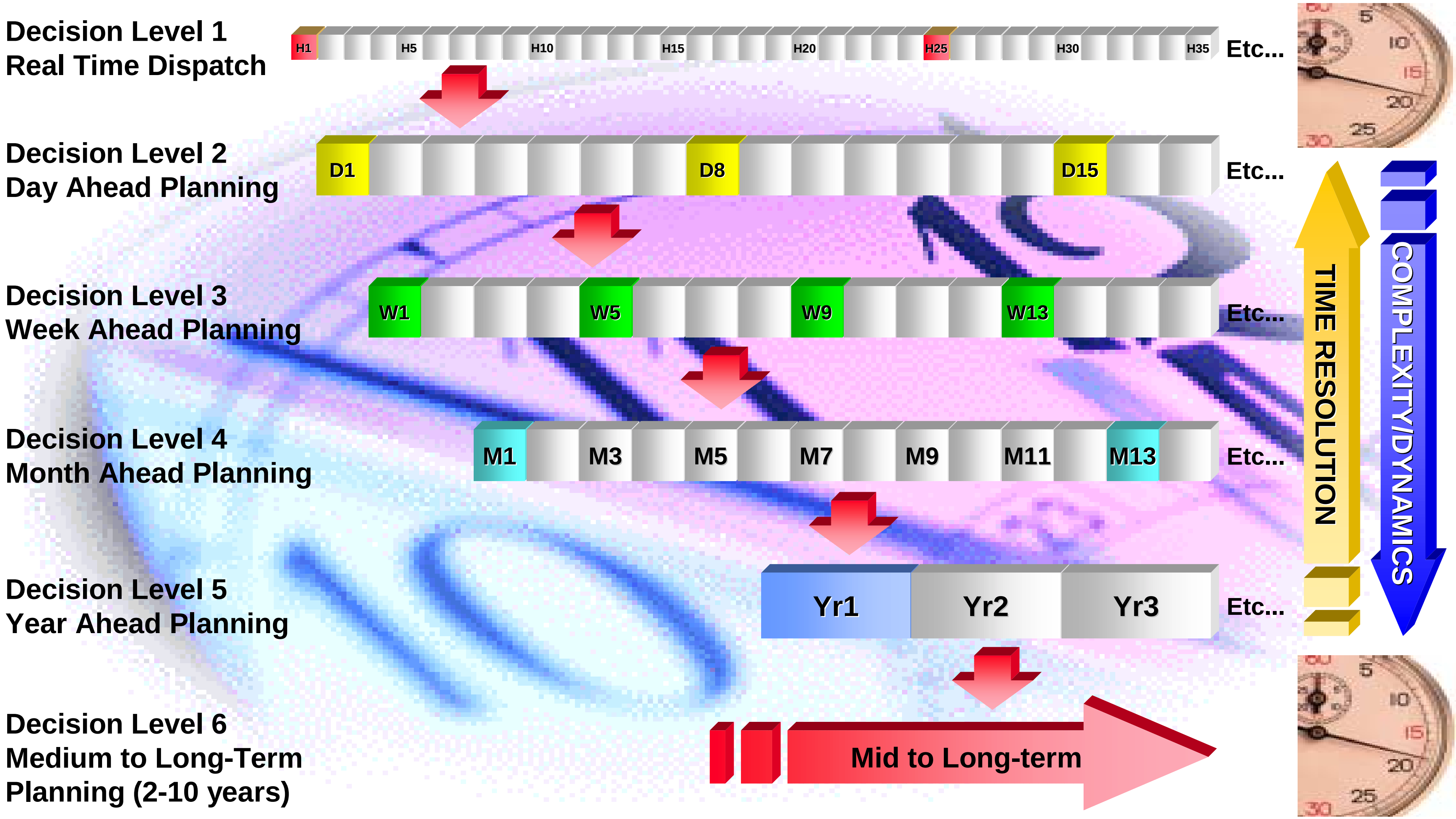
LOOK SIDEWAYS
- ***Competing unit availability***
- ***Own cost structure***
- ***Market rules***

LOOK BACK (Short and Long-Term Memory)
- ***Bid accepted/rejected***
- ***Unit utilization***
- ***Unit profitability***
- ***Market price vs bid price***
- ***Weather & Load***

DECISION OUTPUT
- ***Bid structure: capacity blocks for different markets***
- ***Bid prices for each block and market***

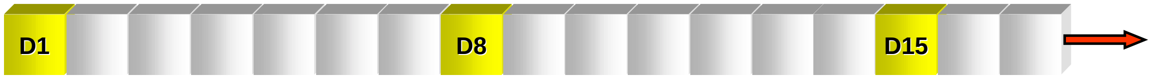
LOOK AHEAD
- ***Own unit availability***
- ***Prices***
- ***Weather***
- ***Load***

EMCAS Operates at Six Time-Based Decision Levels That are Interdependent



Level 2 – Day Ahead Planning
Companies Decide on Next Day Strategies

Decision Level 2
Day Ahead Planning



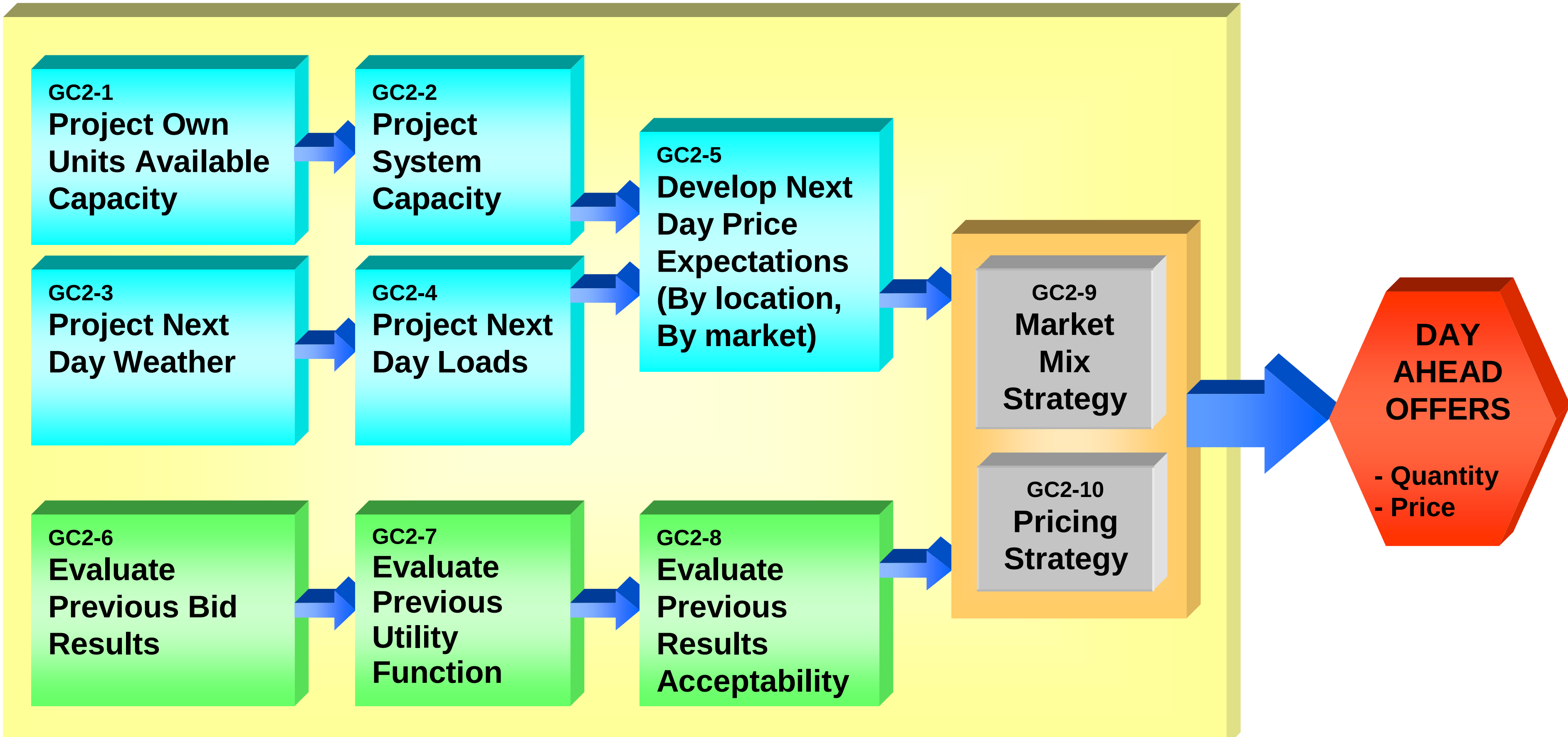
Generation Company

- Longer-term bilateral contracts in place
- Must make unit commitment and pricing decisions
  - Energy market
  - Ancillary services market
  - Day ahead bilateral contract

Demand Company

- Longer-term bilateral contracts in place
- Must make purchase decisions
  - Energy market
  - Day ahead bilateral contract

Level 2 – Day Ahead Planning
Generation Company Internal Model



Each generation company may use different methods for each component of its internal model

Level 2 – Day Ahead Planning
Generation Company Strategies

- **Possible Market Mix Strategies**
  - Bid all capacity into energy (spot) market
  - Offer all capacity under day ahead bilateral contracts
  - Offer fixed increments into each market
  - Withhold capacity from some or all markets
  - Increment mix from previous days based on performance
  - …others…
- **Possible Pricing Strategies**
  - Bid production cost
  - Bid to ensure dispatch
  - Bid to increase the market clearing price
  - Bid last increment of capacity at high price (hockey stick bidding)
  - Adjust prices from previous days based on performance
  - …others…

Initial company strategies based on market rules are input as part of the initial conditions

Level 2 – Day Ahead Planning
Company Strategies Are “Tuned” at this Level

Example: Generation Company Strategy

- **-Bid all capacity into Energy (Spot) Market**
- **-Attempt to increase Energy Market Clearing Price**

Next Day Energy Market Bid Price $= \alpha \times$ ***Production Cost***

Examples for Strategy Tuning Rules

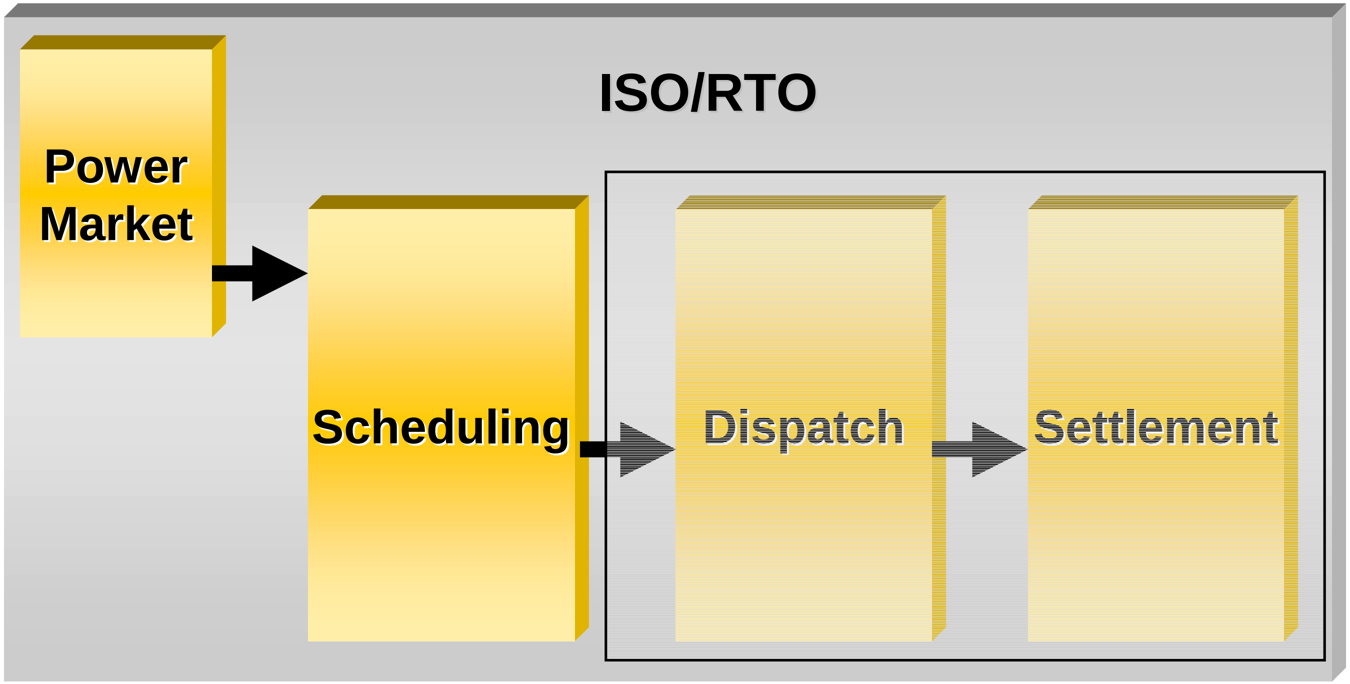
If previous day bid accepted $\alpha = \alpha$ **(previous day) x 1.05**

If previous day bid rejected $\alpha = \alpha$ **(previous day) x 0.95**

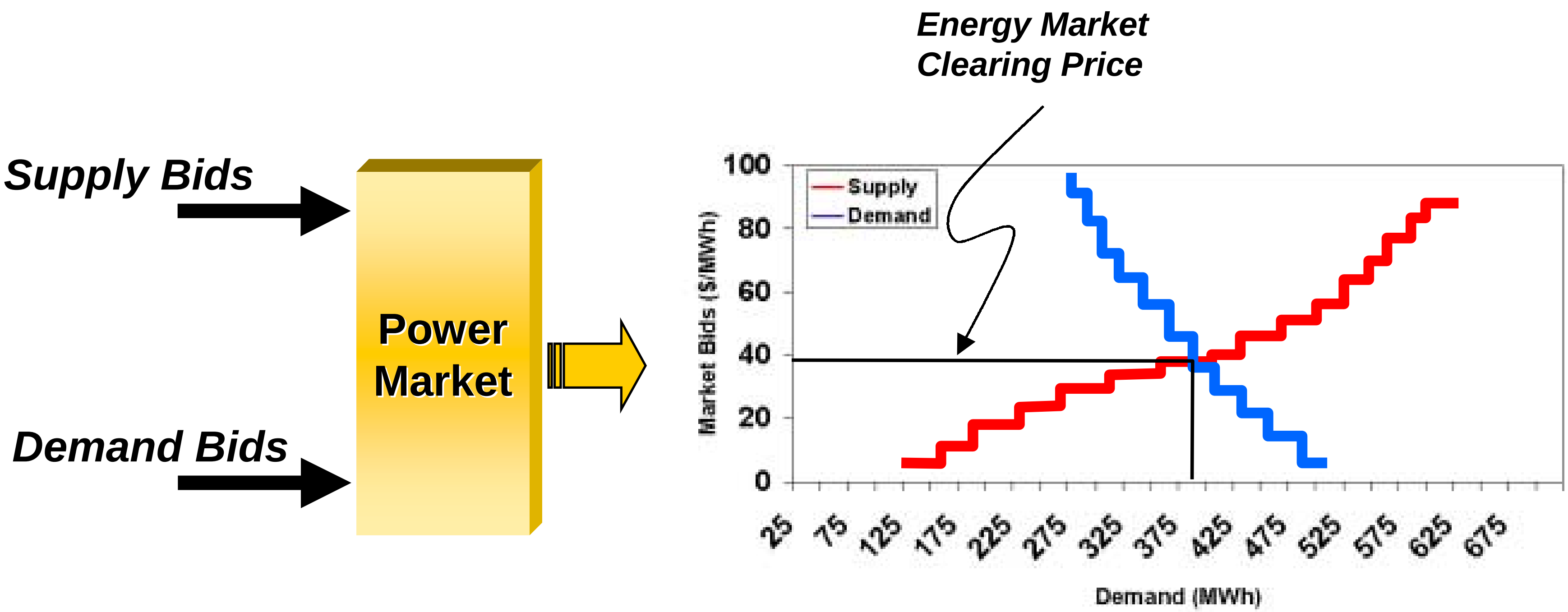
Company agents can switch strategies. The decision to switch is made at higher Decision Levels

Level 2 – Day Ahead Planning

The ISO/RTO Exercises Two of Its Functions at this Level



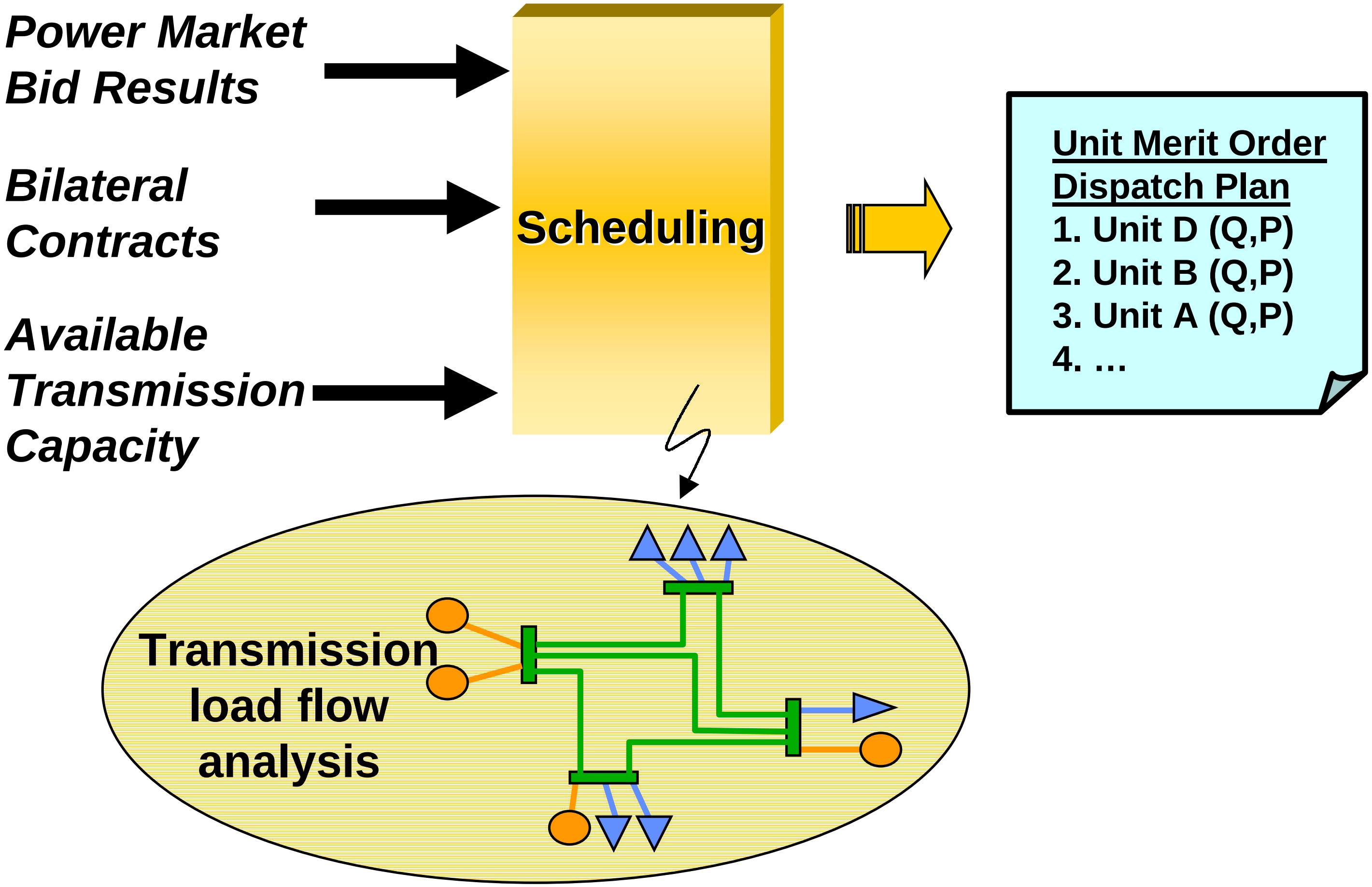
Level 2 – Day Ahead Planning
The Power Market Function
Ranks the Supply and Demand Bids Received



The Power Market includes
Energy and Ancillary Services

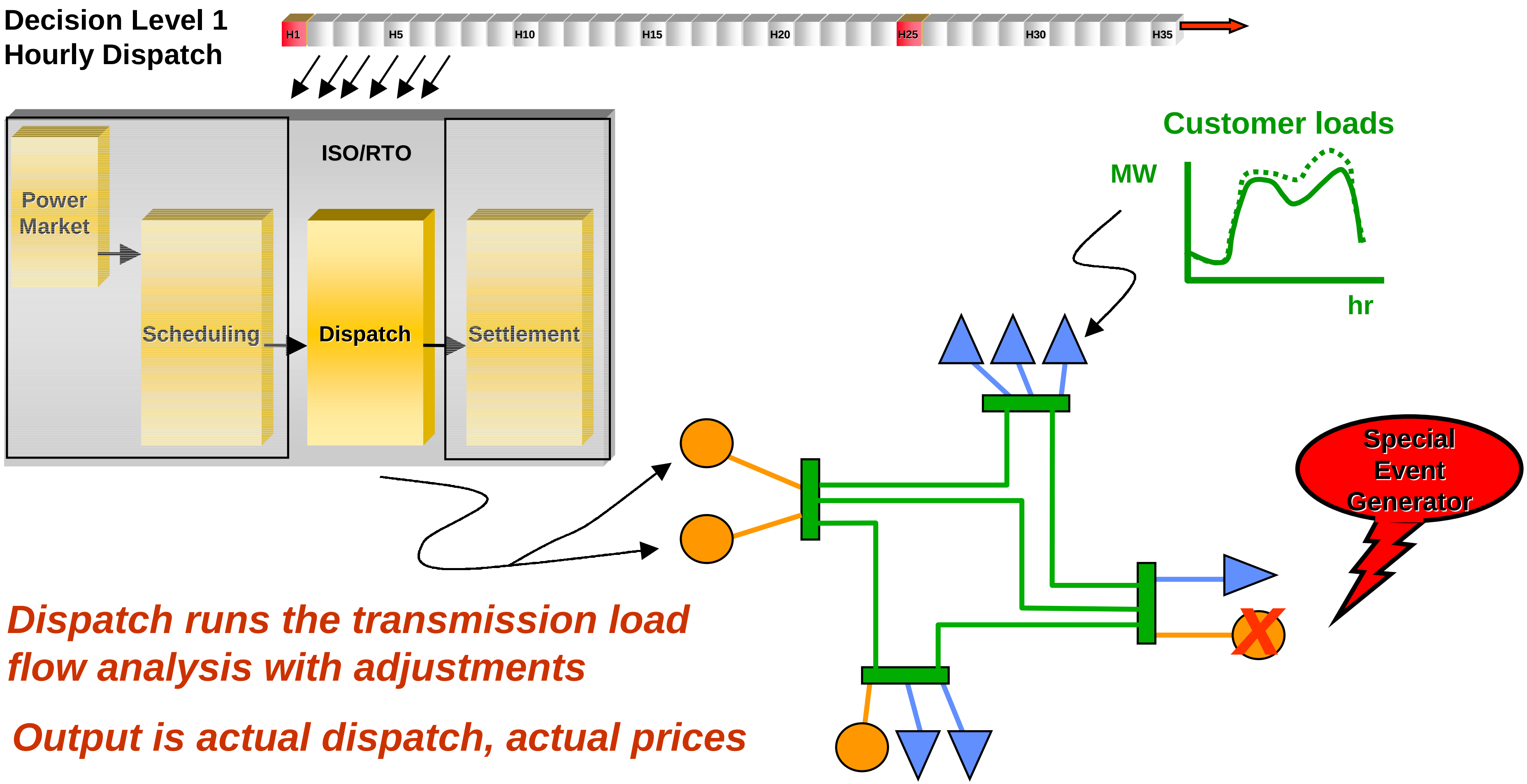
Level 2 – Day Ahead Planning

Scheduling Combines Power Market Results, Bilateral Contracts, and Transmission Availability



Level 1 – Hourly Dispatch

The ISO/RTO Dispatch Function Dispatches the System to Match Actual Supply and Demand

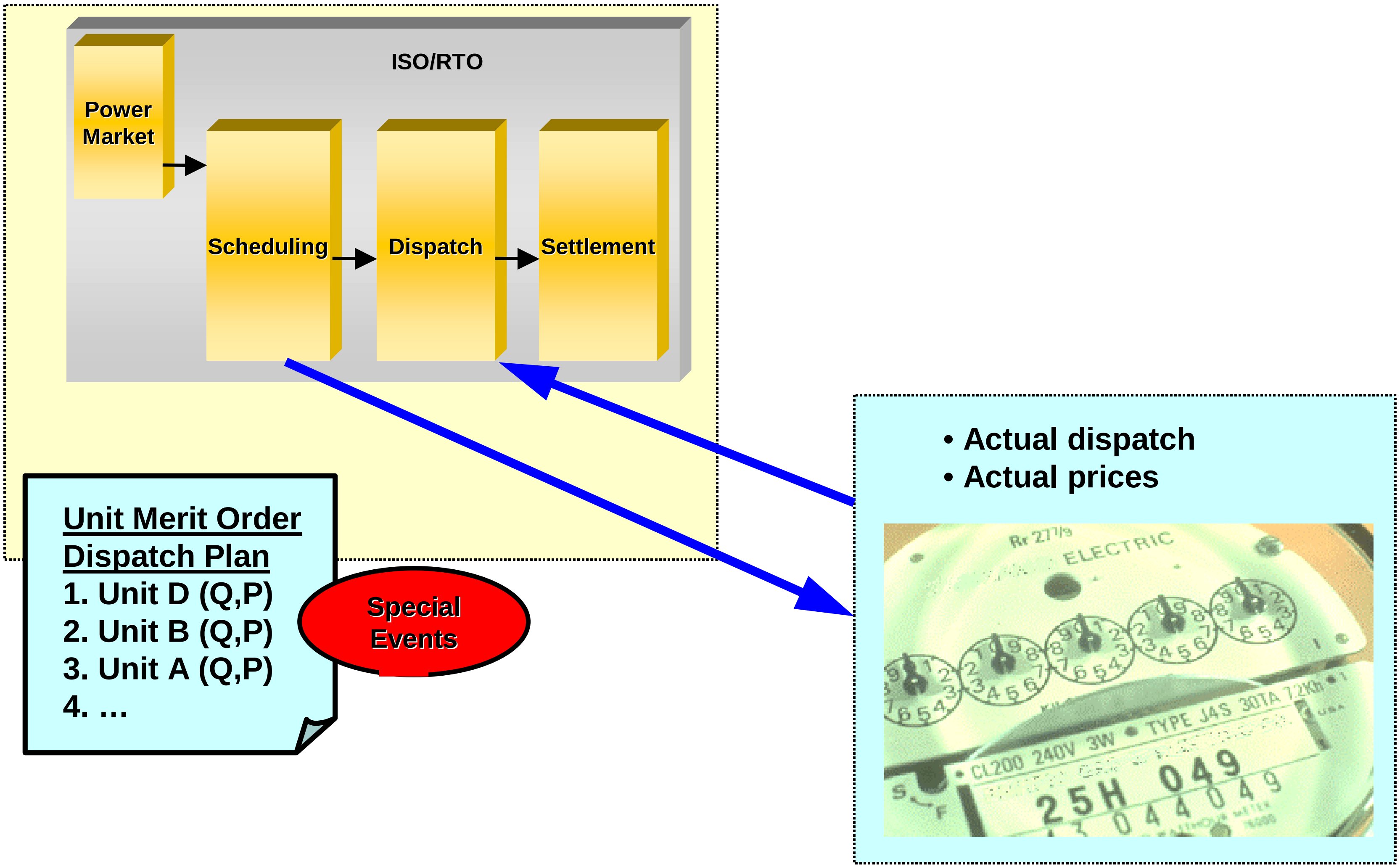


Dispatch runs the transmission load flow analysis with adjustments

Output is actual dispatch, actual prices

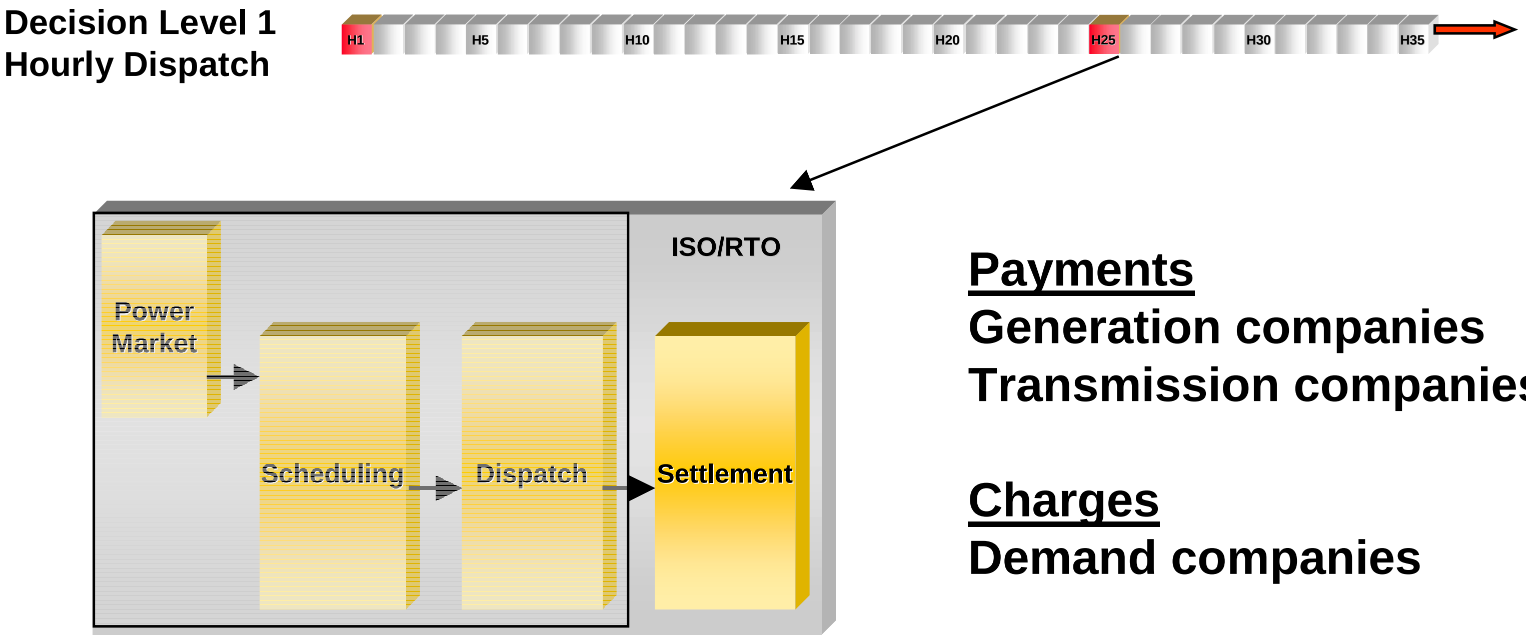
Level 1 – Hourly Dispatch

The Interface With the Transmission Model Is During Scheduling and Dispatch



Level 1 – Hourly Dispatch

The ISO/RTO Settlement Function Computes Charges and Payments Based on Settlement Rules



<u>Payments</u>
Generation companies
Transmission companies

<u>Charges</u>
Demand companies

Company "profits" are calculated

Customer charges are calculated

Level 4 – Month Ahead Planning

Companies and Customers Make Adjustments to Their Day Ahead Strategies

Decision Level 4
Month Ahead Planning

M1 M3 M5 M7 M9 M11 M13

Generation Company

- Evaluate and adjust company day ahead strategies

Demand Company

- Evaluate and adjust company day ahead strategies

Customers

- Adjust electricity use in response to prices
- Select alternate supplier and/or supply terms

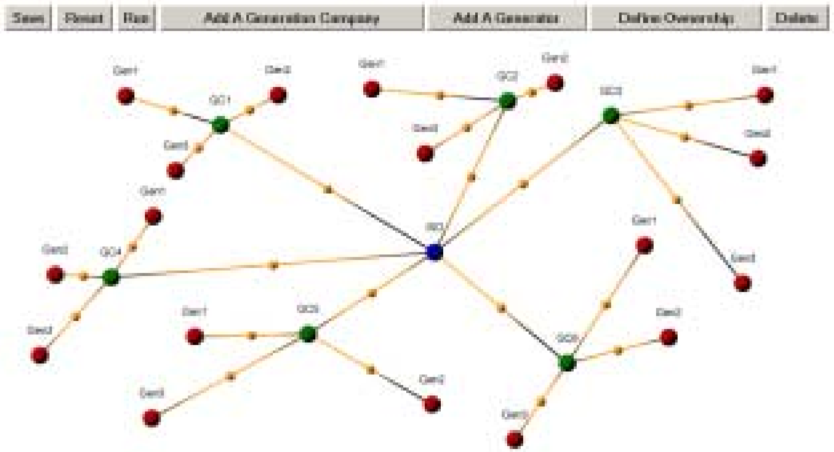
The User-Controlled Regulator Can Change the Market Rules

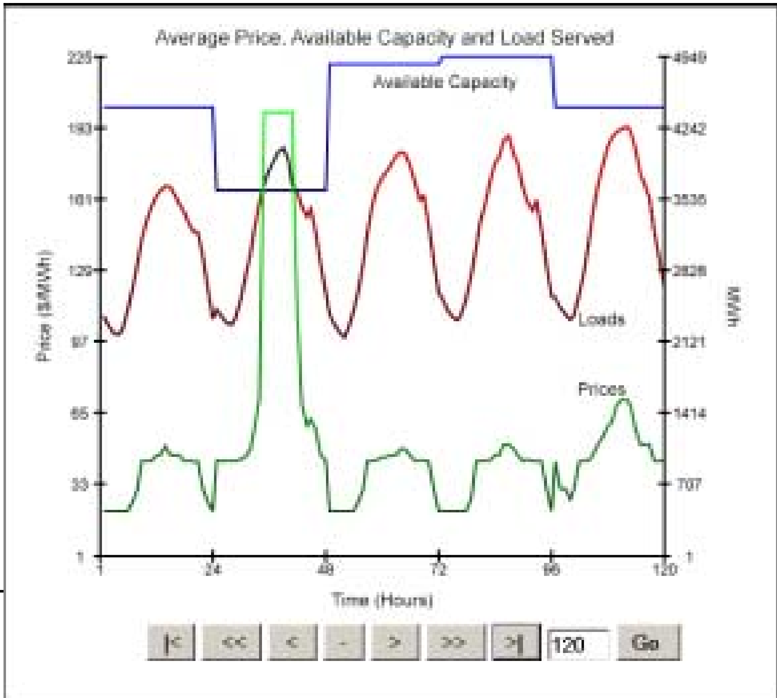
Regulator

- **Change settlement (payment) rules**
  - Pay Market Clearing Price
  - Pay as Bid
  - Payments for unscheduled dispatch
  - Transmission congestion charges
  - …others…
- **Change bilateral contract rules**
  - Allow/Disallow bilateral contracts
  - Transmission contracts
  - …others…
- **Pricing rules**
  - Price caps
  - Customer tariffs
  - …others…
- **Others**

There are Multiple Advantages to the EMCAS Agent-Based Simulation

- Decentralized decision making is represented
- Alternative company strategies can be simulated
- Adaptation occurs in the simulation
- Market rules can be tested
- Transient conditions can be studied
- Contributors to system problems can be identified

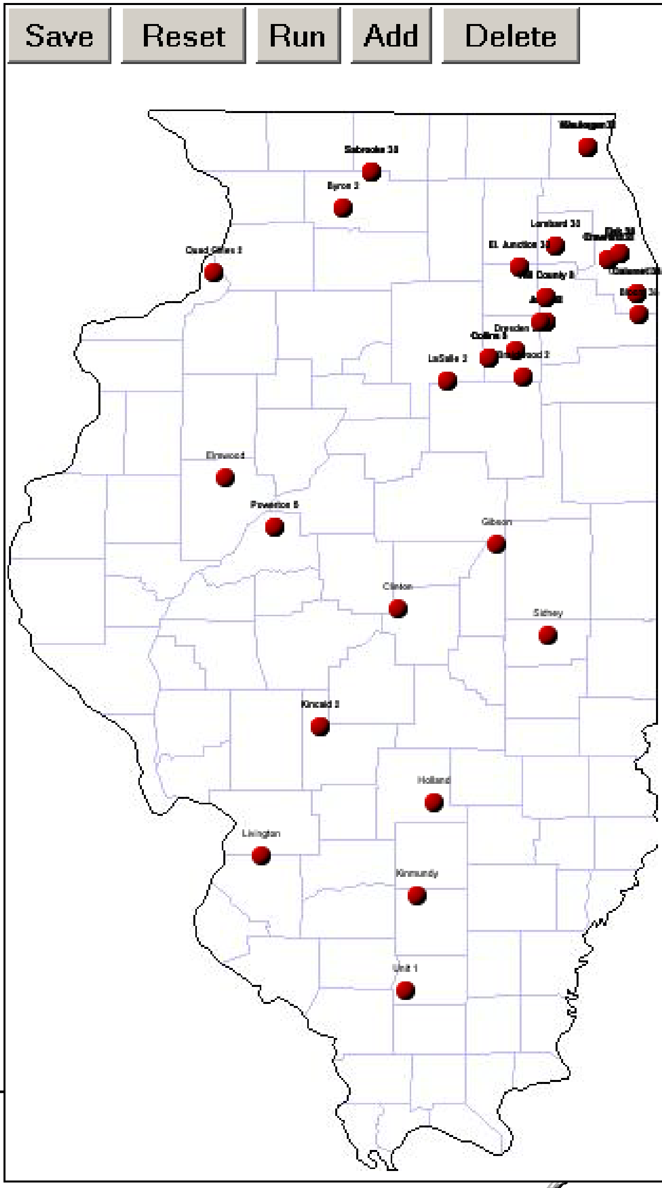




ANL is Using EMCAS to Evaluate the Potential Impacts of Transmission Constraints on the Operation of a Competitive Electricity Market in Illinois

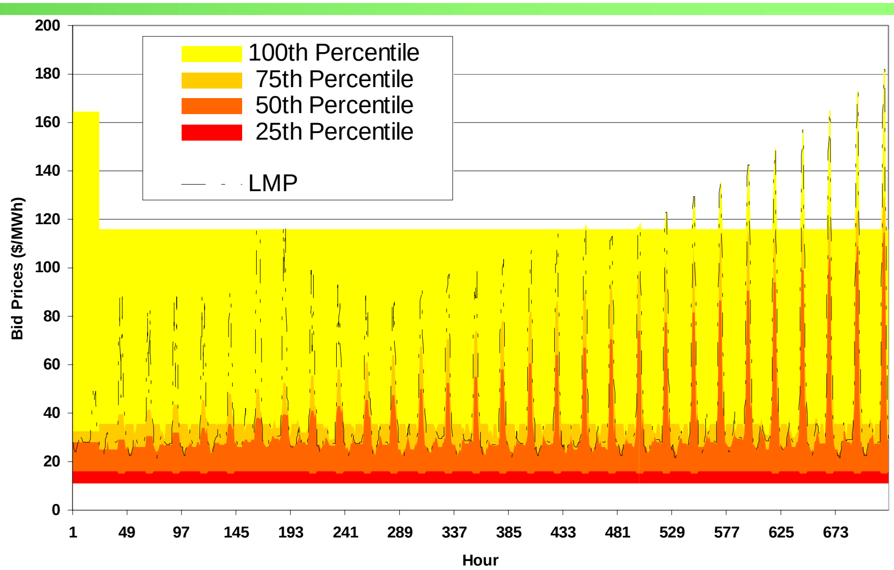
- **Study will determine if transmission system in Illinois and the surrounding region can support a competitive electricity market**
  - Will it support effective competition to keep prices in check
  - Will it allow for new market participants to effectively compete for market share
  - Could conditions occur that would enable a company to exercise market power in one or more portions of the state and thereby create undue pressure on the prices
  - Could conditions occur that would enable a company to inhibit new market participants from entering the market

- **Analysis is conducted in several stages**
  - Identify basic problem areas
  - Analyze competitive market structure and behavior
  - Analyze effect of adding new generation resources
  - Analyze effect of adding new transmission resources
  - Analyze effect of alternative market rules



EMCAS Application and Sample Results

- **EMCAS 30-day simulation showing distribution of generation company price bids in a competitive market. The top 25% of the bids (yellow zone) have the greatest impact on the locational market price. Price spikes are the result of outages in the simulation that prompt companies to increase their bids**



- **EMCAS simulation showing company 30-day profits under different market conditions and different market settlement rules. In this example, one company dominates this market**